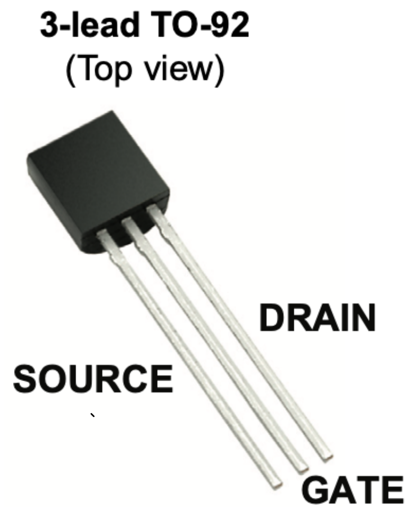
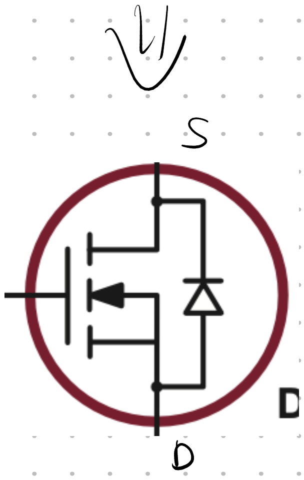
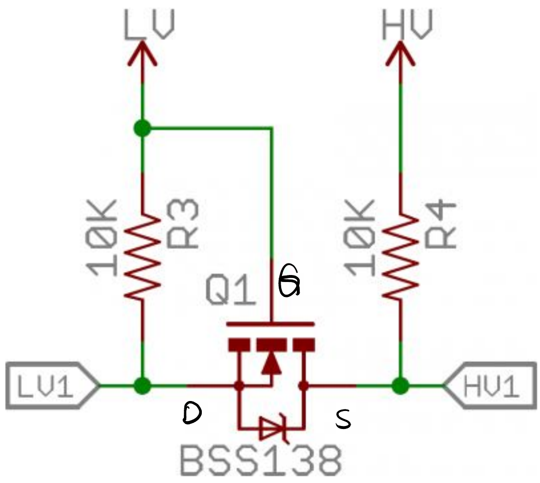
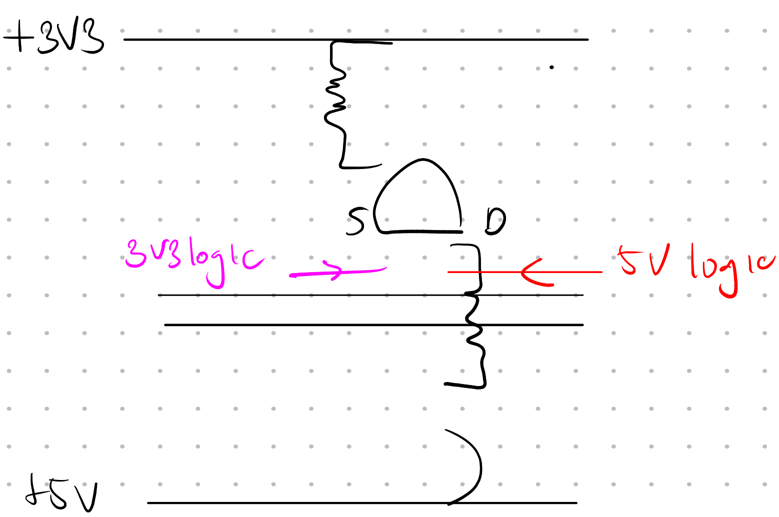


from stack exchange:
https://electronics.stackexchange.com/questions/555631/understanding-how-this







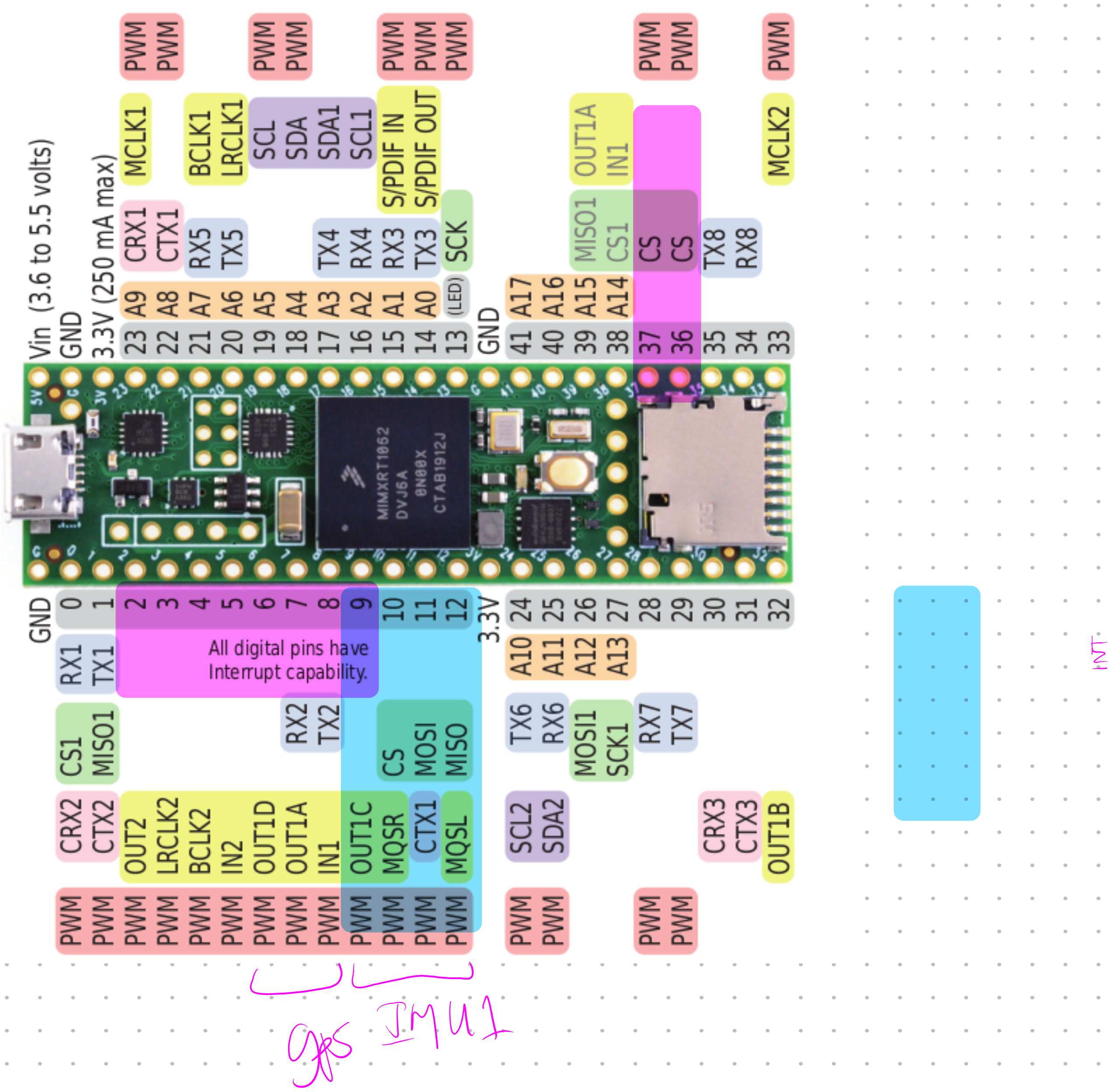
5v 3v3

test		output	
'0'	'1'	'0'	'1'
0v	5v	0v5081	3v339
0v	3v3	0v5081	3v339

in conclusion: using the 2n7000 isn't going to work bc it doesn't pull the ckt high enough on the 5v output

WRONG CONCLUSION

flip the source and drain --> the LV and HV sides and it works just fine!
the problem from before was that the gate was NOT pulled high enough (translation: I didn't connect the gate correctly the first time)



Vin (3.6 to 5.5 volts)
GND
3.3V (250 mA max)
23 A9 CRX1 MCLK1 PWM
22 A8 CTX1 PWM
21 A7 RX5 BCLK1
20 A6 TX5 LRCLK1
19 A5 SCL PWM
18 A4 SDA PWM
17 A3 TX4 SDA1
16 A2 RX4 SCL1
15 A1 RX3 S/PDIF IN PWM
14 A0 TX3 S/PDIF OUT PWM
13 (LED) SCK PWM
GND
41 A17
40 A16
39 A15 MISO1 OUT1A
38 A14 CS1 IN1
37 CS PWM
36 CS PWM
35 TX8
34 RX8
33 MCLK2 PWM
GND
0 RX1 CS1 CRX2 PWM
1 TX1 MISO1 CTX2 PWM
2 OUT2 PWM
3 LRCLK2 PWM
4 BCLK2 PWM
5 IN2 PWM
6 OUT1D PWM
7 RX2 OUT1A PWM
8 TX2 IN1 PWM
9 OUT1C PWM
10 CS MQSR PWM
11 MOSI CTX1 PWM
12 MISO MQSL PWM
3.3V
24 A10 TX6 SCL2 PWM
25 A11 RX6 SDA2 PWM
26 A12 MOSI1
27 A13 SCK1
28 RX7 PWM
29 TX7 PWM
30 CRX3
31 CTX3
32 OUT1B
All digital pins have
Interrupt capability.
MIMXRT1062
DVJ6A
0N00X
CTAB1912J
gps
IMU1
INT

$${}^{I}_{G}q = \sum \dot{q} \cdot \Delta t \quad (1)$$

rate of change of q can be approximated using

$${}^{I}_{G}\dot{q} = \frac{1}{2}\, {}^{I}_{G}\hat{q} \cdot \begin{pmatrix} 0 & (\omega - ke) \end{pmatrix}^T \quad (2)$$

gyroscopic error 'e'

* if k is small, ω is considered more

error calcs: → 3-24

reference for gravity:

$$\vec{v}_{r(a)} = \begin{pmatrix} 0 & 0 & -1 \end{pmatrix} \quad (3)$$

using estimates $q = (q_w \ q_x \ q_y \ q_z)$:

$${}^{L}\vec{v}_{r(a)} = \underset{(5)}{q\,\vec{v}_{r(\vec{a})}\,q^{-1}} = \underset{(6)}{R_q \vec{v}_{r(\vec{a})}}$$

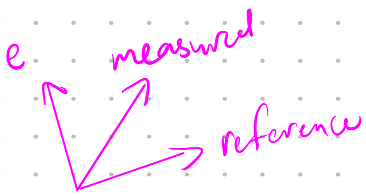
$$R_q(\vec{q}) = \begin{pmatrix} q_w^2 + q_x^2 - q_y^2 - q_z^2 & \cdots & 2q_xq_z - 2q_wq_y \\ \vdots & \ddots & 2q_yq_z + 2q_wq_x \\ & & q_w^2 - q_x^2 - q_y^2 + q_z^2 \end{pmatrix} \quad (7)$$

$$\vdots$$

$${}^{L}v_{r(\vec{a})} = \begin{pmatrix} 2(q_xq_z - q_wq_y) \\ 2(q_wq_x + q_yq_z) \\ 2(q_w^2 + q_z^2) - 1 \end{pmatrix}^T \quad (8)$$

from normalized $\vec{q}$ equation

error e is calculated from two error terms. all vectors are normalized before calculations:



$$\hat{v} = \frac{\vec{v}}{|\vec{v}|} \quad (11)$$

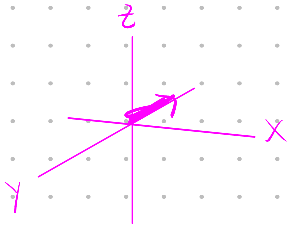
$$e_a = \begin{pmatrix} x_\theta \\ y_\theta \\ z_\theta \end{pmatrix} = \hat{v}_{m(a)} \times {}^{L}\vec{v}_{r(a)} \quad (12)$$

to remove for magnetic incliination:

consider only x & z!

$$\vec{v}_{r(m)} = (v_{rx} \quad 0 \quad v_{rz}) \quad (13)$$

$$\vec{v}_{r(e)} = (0 \quad 0 \quad -1) \times (v_{rx} \quad 0 \quad v_{rz}) \quad (14)$$



$$= (0 \quad -1 \quad 0) \quad (15)$$

$$^{L}\vec{v}_{r(m)} = q\vec{v}_{r(m)}q^{-1} \quad (16)$$

doing the same for magnetic inclination: (6), (7) --> (15), (16)

$$^{L}\vec{v}_{r(m)} = \begin{pmatrix} 2(q_x q_y + q_w q_z) \\ 2(q_w^2 + q_y^2) - 1 \\ 2(q_y q_z - q_w q_x) \end{pmatrix} \quad (17)$$

$$\vec{e}_m = \begin{pmatrix} x_\theta \\ y_\theta \\ z_\theta \end{pmatrix} = \left| \hat{v}_{m(\vec{a})} \times \hat{v}_{m(\vec{m})} \right| \times {}^{L}\vec{v}_{r(\vec{m})} \quad (18)$$

these are here for some reason...

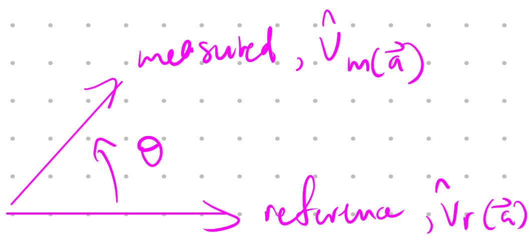
$$\vec{e} = e_a + e_m \quad (19)$$

but it needs to change based on the conditions

$$\vec{e} = \begin{cases} \vec{e}_a + \vec{e}_m & |\vec{v}_{m(\vec{a})}| > 0 \ \&\& \ |\vec{v}_{m(\vec{m})}| > 0 \\ \vec{e}_m & |\vec{v}_{m(\vec{m})}| > 0 \\ (0 \quad 0 \quad 0)^T & \end{cases} \quad (20)$$

apparently this can be conbined with the gyroscopic integration to provide with an accurate correction factor of gyroscopic drift.

B. Universal convergence:



this mathemtical relationship can be described using the scalar version of this formula where

$$0 < \theta < \pi \quad \text{(radians)}$$

so:

(estimate from the next timestep?)

$$|\vec{e}_a| = \underbrace{|\vec{v}_{m(a)}| \cdot |{}^{L}\vec{v}_{r(a)}|}_{1\text{, b/c they're normalized}} \sin\theta \quad (22)$$

$$\hookrightarrow |\vec{e}_a| = \sin\theta \quad (22a) \rightarrow |\vec{e}_a| = \theta \text{ for small } \theta \quad (22b)$$

since the gravity error term is normalized, the formula simplifies to the above formulas

also, the proper gain K must be smaller than 1 to get a stable convergence!

C. Magnetic Disturbance rejection
magnetic sources, whether ferromagnetic or diamegnetic, are everywhere. it distorts the overall signal where it is around 0.2 to 0.65 Gauss when considering all possible locations (though it can be very consistent on a local scale!)

what Madgwick et al does is reject magnitudes above or below this range!

$$\vec{V}'_{m(m)} = \begin{cases} \vec{V}_{m(m)} & \text{for } m_{min} < |\vec{V}_{m(m)}| < m_{max} \\ (0\ 0\ 0)^T & \text{otherwise} \end{cases} \quad (23)$$

total error conditions, then, considering the above conditions:

$$\vec{e} = \begin{cases} \vec{e}_a + \vec{e}_m & |\vec{V}_{m(\vec{a})}| > 0 \ \&\& \ m_{min} < |\vec{V}_{m(m)}| < m_{max} \\ \vec{e}_a & m_{min} < |\vec{V}_{m(m)}| < m_{max} \\ (0\ 0\ 0)^T & \end{cases} \quad (24)$$

D. Magnetic Disturbance Compensation
there are a few reasons for why this is not an effective long-term solution. turning this off leaves the the IMU estimator susceptible to gyroscope drift. we have to add compensation. Keyframes are instances during a movement that define it and leaves interpolation to define the in-between frames.

Keyframes can be used to determine magnetic samples of minimal magnetic interference or gyroscopic drift.

this is achieved by calibrating hte gyroscopes and them performing the range of motions once.

quaternion q represents the movement due to accel and mag reference. so the accelerometer and magnetometer vectors that converge to q can be calculated by substituting 3 and 15 into 5 to produce the following values:

$\vec{V}_{SIM(\vec{a})}$ & $\vec{V}_{SIM(\vec{m})}$

$$\text{ISBIO}: \quad \vec{V}_{r(\vec{a})} = (0\ 0\ -1)^T \quad (3)$$

$$\vec{V}_{r(\vec{m})} = (0\ -1\ 0) \quad (15)$$

given

$$\vec{V}_{SIM(\vec{a})}(\vec{q}) = \vec{q}\,\vec{V}_{r(\vec{a})}\,\vec{q}^{-1} \ \& \quad (25)$$
$$\vec{V}_{SIM(\vec{m})}(\vec{q}) = \vec{q}\,\vec{V}_{r(\vec{m})}\,\vec{q}^{-1}$$

each keyframe therefore consists of these two 3D vectors.

whne magnetometer is unavailable, accelerometer is compared against V_sim(a). the keyframe with the smallest differences between the two frames is taken as the system estimation.

$$\vec{e}_{SIM(m)} = \hat{V}_{m(\vec{a})} \times \hat{V}_{SIM(m)} \times {}^{L}\vec{V}_{r(\vec{m})} \quad (26)$$ rotated vector using prev q

$$\vec{e} = \begin{cases} \vec{e}_a + \vec{e}_m & |\vec{V}_{m(\vec{a})}| > 0 \ \&\& \ m_{min} < |\vec{V}_{m(m)}| < m_{max} \\ \vec{e}_a + \vec{e}_{SIM(m)} & |\vec{V}_{m(\vec{a})}| > 0 \\ (0\ 0\ 0)^T & \end{cases}$$

Compare:

$$\vec{e}_m = \begin{pmatrix} x_\theta \\ y_\theta \\ z_\theta \end{pmatrix} = \hat{V}_{m(\vec{a})} \times \hat{V}_{m(\vec{m})} \times {}^{L}\vec{V}_{r(\vec{m})} \quad (18)$$

$$\vec{e}_{SIM(m)} = \hat{V}_{m(\vec{a})} \times \hat{V}_{SIM(m)} \times {}^{L}\vec{V}_{r(\vec{m})} \quad (26)$$

E. Gain K

I guess K is able to change. in normal use, K will be low so the gyroscopic integration can be incorporated. See (2). it's defined as K_norm. that's the K that's used in normal conditions. for initial convergence, it should be K_init and should transition to K_norm. the following is (28).

$$K = \begin{cases} K_{norm} + \dfrac{t_{init} - t}{t_{init}}\left(K_{init} - K_{norm}\right) \\ K_{norm} \end{cases} \qquad (28)$$

K_norm, K_init, and t_init are found by examining the behavior of the alg and tuned for specific effects. However, the values K_init = 10, provide fast convergence because the error is expected to be high; and K_norm = 10 after t_init at 3 seconds provide good performance